Superior outcomes for rural patients after abdominal aortic aneurysm repair supports a systematic regional approach to abdominal aortic aneurysm care

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Objective: **The impact of geographic isolation on abdominal aortic aneurysm (AAA) care in the United States is unknown. It has been postulated but not proven that rural patients have less access to endovascular aneurysm repair (EVAR), vascular surgeons, and high-volume treatment centers than their urban counterparts, resulting in inferior AAA care. The purpose of this study was to compare the national experience for treatment of intact AAA for patients living in rural areas or towns with those living in urban areas.**

Methods: **Patients who underwent intact AAA repair in 2005 to 2006 were identified from a standard 5% random sample of all Medicare beneficiaries. Data on patient demographics, comorbidities, type of repair, and specialty of operating surgeon were collected. Hospitals were stratified into quintiles by yearly AAA volume. Primary outcomes included 30-day mortality and rehospitalization.**

Results: **A total of 2616 patients had repair for intact AAA (40% open, 60% EVAR). Patients from rural and urban areas were equally likely to receive EVAR (rural 60% vs urban 61%; $P = .99$) and be treated by a vascular surgeon (rural 48% vs urban 50%; $P = .82$). Most rural patients (86%) received care in urban centers. Primary outcomes occurred in 11.6% of rural patients (1.3% 30-day mortality; 10.3% rehospitalization) vs 16.0% of urban patients (3% 30-day mortality, 13% rehospitalization; $P = .04$). In multivariate analyses, rural residence was independently associated with treatment at high-volume centers (odds ratio, 1.64; 95% confidence interval, 1.34-2.01; $P < .0001$) and decreased death or rehospitalization (odds ratio, 0.69; 95% confidence interval, 0.49-0.97; $P = .03$).**

Conclusions: **Despite geographic isolation, patients in rural areas needing treatment for intact AAAs have equivalent access to EVAR and vascular surgeons, increased referral to high-volume hospitals, and improved outcomes after repair. This suggests that urban patients may be disadvantaged even with nearby access to high-quality centers. This study supports the need for criteria that define centers of excellence to extend the benefit of regionalization to all patients. (J Vasc Surg 2012;56:608-13.)**

Abdominal aortic aneurysms (AAAs) represent a significant ongoing health concern for the elderly population. Several factors have been associated with improved outcomes after AAA repair, including endovascular aneurysm repair (EVAR), surgery performed in high-volume centers, and surgery by those with specialized vascular training.[1–5] No prior studies have examined the availability of this level of AAA care for the 15% to 20% of the US population that lives in rural areas. However, rural patients have reduced access to health care, and studies of other complex medical conditions such as cancer have found that rural patients are disadvantaged compared with their urban counterparts[6,7] with regard to initial stage, initial treatment, posttreatment surveillance, and participation in clinical trials. Other studies have shown that ethnicity and insurance type influence access to high-volume centers and surgical outcomes after AAA repair.[8,9]

Using patient-level data, we aimed to describe the national experience for treatment of intact AAAs for patients living in rural areas, identify differences in treatment characteristics between rural and urban AAA patients, and determine the effect of treatment differences on outcomes. We hypothesized that patients residing in rural areas or towns would be less likely to undergo EVAR, less likely to be treated in a high-volume center or by a vascular surgeon, and would experience higher mortality and readmissions.

METHODS

This study was conducted as a retrospective analysis using data of Medicare beneficiaries who underwent surgery for intact AAAs in 2005 and 2006. Data were obtained

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from the Centers for Medicare & Medicaid Services through the Chronic Condition Data Warehouse, administrated by the Iowa Foundation for Medical Care. This dataset includes a random 5% sample of all Medicare patients in the United States, and unique to the Chronic Condition Data Warehouse, any beneficiary that enters the cohort will remain in the cohort from that time forward. Inpatient files, outpatient files, and denominator files were available for data extraction. Each record included demographics, physician and hospital identifiers, and diagnosis and procedure codes as classified by the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM).

The included patients were Medicare beneficiaries receiving surgical treatment for AAAs between January 1, 2005, and December 1, 2006, that had been continuously enrolled in Medicare part A and part B for at least 365 days before the date of the index procedure to allow full characterization of baseline comorbidities. Patients with a diagnosis of intact AAA (ICD-9-CM codes 441.4 and 441.9) and an open or endovascular procedural code during the index hospitalization (codes 38.34, 38.44, 38.64, 39.52, and 39.71) were analyzed. Ruptured aneurysms (441.3) were excluded, as were aortic dissections, thoracic aneurysms, thoracoabdominal aneurysms, or aneurysm diagnoses without an associated treatment code. Also excluded were those with incomplete enrollment in Medicare part A (hospital claims) and B (physician claims) for 12 months preceding surgery, enrollment in a Medicare health maintenance organization, or having railroad benefits at any time from entry into Medicare through December 31, 2006.

Patient demographic data collected included age, gender, race, and eligibility for Medicaid during the study period. Patient comorbidities were estimated using the Centers for Medicare and Medicaid Services - Hierarchical Condition Categories scale.[10-13] This validated measure of comorbidity uses 12 months of inpatient and ambulatory claims to calculate predicted expenditures in future years. Over 3000 ICD-9-CM diagnosis codes are divided into 70 Condition Categories (CCs).[10] Within each CC, hierarchies are used to characterize each person's level of illness within each disease process. For example, within the Coronary Artery Disease hierarchy, four CCs are arranged in descending order of clinical severity and cost, from CC 81 Acute Myocardial Infarction to CC 84 Coronary Atherosclerosis. A patient with an ICD-9-CM code within CC 81 is excluded from being coded in CCs 82 to 84 even if codes within these groups are present.

Hierarchical Condition Categories also accounts for significant interactions between CC categories that have substantial effects on cost. For example, simultaneous presence of congestive heart failure and chronic obstructive pulmonary disease leads to higher costs than would be predicted by adding predicted increments of congestive heart failure and chronic obstructive pulmonary disease alone. The score, therefore, is an estimation of the presence and severity of medical comorbidity, as patients with more medical conditions and increased illness for a given condition will incur more medical expenses. By convention, a score of 1 represents the predicted cost of an average Medicare patient.

Residence was grouped into rural, large-town, or urban area using US Department of Agriculture census-based Rural Urban Commuting Area (RUCA) codes.[14,15] Each ZIP code was converted to an RUCA code based on both population size and commuting patterns and has advantages over previous classification systems in that less densely populated ZIP codes adjacent to or within metropolitan areas are not misclassified as rural areas. Additionally, differences within counties (eg, one urban ZIP code surrounded by rural ZIP codes) are captured. Rural areas were defined as population of less than 10,000 and included RUCA codes 7, 7.3, 7.4, 8, 8.3, 8.4, 9, 9.1, 9.2, 10, 10.3, and 10.5. Large towns (populations of 10,000-50,000) included RUCA codes 4, 5, 6, 7.2, 8.2, and 10.2, and urban areas (populations >50,000) included RUCA codes 1, 2, 3, 4.1, 7.1, 8.1, and 10.1.

Treatment variables included type of AAA repair, yearly hospital AAA repair volume, and operating physician specialty. The primary outcome variable was 30-day mortality or rehospitalization within 30 days of the primary procedure. Yearly hospital volume was categorized into quintiles, based on work by Birkmeyer et al.[16] Hospitals in the highest quintile were defined as high-volume hospitals. Physician specialty was determined by unique physician identifier number.

Variables were compared with χ^2, Fisher exact test, *t*-test, analysis of variance, or Wilcoxon rank-sum test when indicated. Data were considered statistically significant with a P value $\leq .05$. Multivariable hierarchical mixed-effects regression models were then used to determine independent correlates for treatment and outcome variables and to adjust for clustering at the hospital level. Statistical analysis was performed using SAS software, version 8.0 (Cary, NC).

RESULTS

A total of 2616 patients were identified who underwent repair for intact AAAs in 2005 and 2006. Mean age was 75.8 ± 6.5 years. Three-fourths of patients were men, and 94% were white. Medically indigent patients, defined as those eligible for Medicaid at any time during the study period, made up 8.5% of the sample.

Most patients (n = 1845; 70%) resided in urban areas. Rural patients (n = 388) and large-town patients (n = 383) each accounted for 15% of the cohort. Comparing patients by type of residence (Table I), rural patients were more likely to be white and more likely to receive Medicaid than their large-town or urban counterparts. No significant differences existed with regard to comorbidity score.

The vast majority of procedures (93.9%) were performed in urban centers; and this was true regardless of type of residence. However, rural patients (86.1%) and large-town patients (77.0%) were less likely to be treated in urban centers than patients residing in urban areas (99.1%; $P <$ .001). Rural patients were also less likely to be treated in

Table I. Demographics

Factor	*Total (n = 2616)*	*Rural residence (n = 388)*	*Large town (n = 383)*	*Urban (n = 1845)*	P *value*
Age					.46
45-64	3.4	4.9	3.9	2.9	
65-74	39.0	39.4	38.6	38.9	
75-84	48.7	48.2	49.1	48.8	
≥85	8.9	7.5	8.4	9.4	
Male gender, %	75.7	74.7	77.8	75.5	.56
Race					<.003
White	94.1	98.2	96.9	92.7	
Black	3.7	1.3	1.6	4.7	
Asian	0.6	0.0	0.3	0.8	
Hispanic	0.7	0.3	0.3	0.9	
Medicaid patients, %	8.5	13.1	8.1	7.6	<.002
Risk-adjustment score	0.97	0.96	1.00	0.97	.64
Treating hospital					<.001
Rural	0.4	1.6	0.8	0.1	
Large town	5.7	12.4	22.2	0.8	
Urban	93.9	86.1	77.0	99.1	

Values represent % unless specified otherwise.

Table II. Treatment characteristics for intact aneurysm repair

Characteristic	*Total (%)*	*Rural/large-town residence (%)*	*Urban residence (%)*	P *value*
Repair type – EVAR	59.7	59.8	59.7	.99
High-volume hospital	19.8	21.5	19.0	.04
Surgeon type				.82
Vascular surgeon	49.7	48.2	50.4	
General surgeon	20.3	21.7	19.7	
Cardiothoracic surgeon	19.3	19.3	19.2	
Other[a]	6.0	6.0	6.0	

EVAR, Endovascular aneurysm repair.
[a]Cardiology (3.1%), radiology (1.6%), unknown (1.2%).

Table III. Multivariate logistic regression of factors predicting treatment at high-volume centers

Factor	*OR*	*95% CI*	P *value*
Rural residence	1.64	1.34-2.01	<.0001
Large-town residence	1.96	1.59-2.42	<.0001
Urban residence			Referent
Age			
45-64	1.17	0.79-1.73	.44
65-74			Referent
75-84	0.96	0.82-1.11	.56
≥85	1.11	0.86-1.43	.43
Male gender, %	1.00	0.85-1.22	.99
Race			
White			Referent
Black	0.85	0.59-1.22	.37
Medicaid	0.82	0.63-1.07	.14
Risk adjustment score	0.98	0.88-1.08	.68

CI, Confidence interval; *OR,* odds ratio.

Table IV. Primary outcomes after repair of intact AAA

Outcome	*Total*	*Rural residence*	*Large town*	*Urban*	P *value*
30-day mortality or rehospitalization, %	14.9	11.6	12.8	16.0	.04
30-day mortality, %	2.6	1.3	2.1	3.0	.13
Rehospitalization, %	12.9	10.3	11.2	13.8	.10

AAA, Abdominal aortic aneurysm.

large-town hospitals than large-town patients (12% vs 22%; $P = .0005$). Length of stay was not different for rural (5.6 ± 6.9 days), large-town (5.6 ± 7.1 days), or urban patients (6.1 ± 7.0 days; $P = .30$).

Treatment characteristics of the cohort are depicted in Table II. Overall, about 60% of AAAs were repaired by EVAR; 25% in high-volume centers; and 50% by vascular surgeons. Rural patients were as likely to receive EVAR and to be treated by vascular surgeons as urban patients. Rural and large-town patients were more likely to be treated in a high-volume center than those residing in urban areas; on multivariate analysis, rural residence (odds ratio [OR], 1.64; 95% confidence interval [CI], 1.34-2.01; $P < .0001$) and large-town residence (OR, 1.96; 95% CI, 1.59-2.42; $P < .0001$; Table III) remained the only independent predictors of treatment at a high-volume center. Of note, age, comorbidity score, race, and poverty did not predict treatment in high-volume centers.

Overall, 30-day mortality or rehospitalization occurred in 14.9% of the cohort. Event rates were lower for rural patients and large-town patients compared with those in urban areas (11.6% vs 12.8% vs 16.0%, respectively; $P <$ .05; Table IV). By individual outcomes, rural patients were less likely to die after repair and were less likely to be readmitted, although these differences did not reach statistical significance (Table IV). On multivariate analysis, rural residence independently predicted a decreased mortality or readmission (OR, 0.70; 95% CI, 0.49-0.97; $P < .05$), as did male gender (OR, 0.70; 95% CI, 0.54-0.89; $P < .005$; Table V). Other factors significantly predicting increased

Table V. Multivariate analysis of variables associated with combined 30-day mortality or rehospitalization

Factor	*OR*	*95% CI*	P *value*
Rural residence	0.69	0.49-0.97	.03
Large-town residence	0.77	0.55-1.07	.12
Urban residence			Referent
Age			
45-64	0.58	0.46-1.89	.16
65-74	0.61	0.42-0.90	.01
75-84	0.86	0.59-1.29	.36
≥85			Referent
Male gender	0.70	0.54-0.89	.004
Race			
White			Referent
Black	1.27	0.72-1.64	.38
Medicaid, %	0.92	0.60-1.39	.70
Risk adjustment score	1.36	1.18-1.56	<.0001
Volume by quintile			
1 (lowest)	1.09	0.77-1.56	.63
2	1.17	0.80-1.71	.42
3	1.36	0.954-1.94	.09
4	1.363	0.953-1.95	.09
5			Referent
Open vs EVAR repair	0.77	059-0.93	.01
Surgeon type			
Vascular		Referent	
General	0.99	0.74-1.34	.69
Cardiothoracic	0.94	0.70-1.27	.97
Other[a]	1.09	0.76-1.57	.64

CI, Confidence interval; *EVAR,* endovascular aneurysm repair; *OR,* odds ratio.
[a]Cardiology (3.1%), radiology (1.6%), unknown (1.2%).

mortality or readmission included predicted utilization (risk-adjustment score) and open repair (Table V). Age 65 to 74 was associated with decreased events compared with other age groups.

DISCUSSION

Our study is the first to describe the national experience for treatment of intact AAAs in the endovascular era for patients living in rural areas. We found that most rural patients travel to urban centers for AAA care. Compared with patients living in urban areas, rural patients undergoing AAA repair had equivalent access to EVAR and surgeons with vascular training, better access to high-volume centers, and improved outcomes.

Lack of local expertise and the need to refer elsewhere for AAA treatment may have allowed rural patients paradoxically improved access to high-volume centers compared with urban patients. This access may, in part, account for the rural patients' improved outcomes, as the potential benefit of AAA treatment at high-volume centers is well-documented.[1,16] Additionally, in the endovascular era, an increasing percentage of AAAs are being performed at high-volume centers; these high-volume centers are also more likely to adopt EVAR.[17] Equivalent access to EVAR for rural patients in our study is consistent with this finding.

Given that care in a high-volume center was not an independent predictor of outcome in multivariate analysis suggests that rural patients had better outcomes not solely from access to these high-volume centers. Some of the rural patients may have been cared for at high-quality low-volume centers or by highly qualified specialists who did not practice at high-volume centers. Thus, superior outcomes of rural patients represent access to high-quality care regardless of volume. These findings are consistent with other research showing that quality and volume are not perfect surrogates[18] and does not quell the controversy over the threshold at which volume improves quality.[19,20]

Many barriers prevent regionalization for complex surgical care. Previous research has shown that patients have a preference for local care and will trade increased mortality for decreased travel distances.[21] In addition, primary care physicians value not only the medical skill of the specialist but also appointment timeliness, quality communication between the specialist and both the patient and referring physician, and the likelihood that the specialist will return the patient to the primary physician.[22] Of less importance to the primary physician are hospital affiliation, office location, and patient convenience. Our study suggests that these barriers can be overcome and patients effectively referred from rural areas for AAA care. These barriers, however, may keep patients living in large towns from receiving care in high-quality urban centers.

Willingness to refer rural patients to urban settings may reflect a severe shortage of qualified resources at rural hospitals. A recent survey of rural hospital administrators identified that two-thirds were either currently recruiting a general surgeon or expected to within 2 years.[23] Additional expenditures required for a viable endovascular program (eg, specially trained personnel, radiologic imaging, and adequate inventory) may prohibit rural hospitals from attracting appropriately trained physicians, even though surgeons have a vital role in the financial viability of these institutions.[24]

Of potential concern is that urban patients had worse outcomes than rural patients. Urban patients had a higher proportion of minorities and those on Medicaid, which may have impacted outcomes. Other researchers have shown that minority patients are less likely to receive complex surgical care in high-volume hospitals for AAAs because they are not referred to such centers.[25] However, urban patients had significantly worse outcomes even after adjusting for race and Medicaid. It is possible that some urban communities do not have high-quality hospitals, and patients would prefer to remain in their own urban area rather than travel to another urban center for care. Alternatively, urban patients are referred for AAA care based on matching hospital affiliation or insurance coverage between the referring physician and specialist, without knowledge or ability of the primary physician to choose a specialist based on expertise and outcomes.

Although rural patients who receive care for AAAs do not have disparate outcomes, rural patients may still be less likely to receive operative care. Rural patients must travel two to three times farther than urban patients to be evaluated by surgical specialists.[6] This geographic isolation may prevent some patients from receiving treatment. Rural patients may also face financial restrictions or cultural factors that prevent access to specialized care. Our dataset did not allow us to test these hypotheses. In addition, once repair is performed, it is unclear if rural patients have adequate long-term follow-up. Although they had fewer readmissions and superior short-term outcomes in this study, we did not examine outcomes after 30 days. Thus, we cannot evaluate whether these patients received appropriate surveillance after EVAR or had long-term access to sophisticated imaging.

Hospital volume may not be representative when extrapolating from the 5% sample. Our study estimated that 44% of procedures were performed in high-volume hospitals in 2005 and 2006, slightly higher to that reported in 2002 to 2004.[17] If hospital volume was overrepresented, our findings may have underestimated the effect of volume on outcomes. However, as rural residence was determined to be a factor predicting care by a high-volume center, we would expect the main effect on outcomes to remain the same.

This study had other limitations. Clinical information such as aneurysm dimension or severity of chronic medical conditions was not available. Additionally, all administrative databases may be subject to coding errors, which may over- or underrepresent the study variables of interest. However, coding errors are less likely for hospitalizations that result in surgical procedures or require specialist care.[26-28]

In summary, we found that most rural patients travel to urban centers for surgical care of AAAs. Despite geographic isolation, patients in rural areas needing treatment for intact AAAs have equivalent access to EVAR and vascular surgeons, increased referral to high-volume hospitals, and improved outcomes after repair. Our findings support the need for better criteria to define centers of excellence for aortic care, which would allow improved outcomes for all patients.

AUTHOR CONTRIBUTIONS

Conception and design: MM, GL, MS
Analysis and interpretation: MM, CB, AK, GL, MS
Data collection: MM
Writing the article: MM
Critical revision of the article: CB, AK, GL, MS
Final approval of the article: MM, CB, AK, GL, MS
Statistical analysis: MM, GL
Obtained funding: MS
Overall responsibility: MM, MS

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